A Complex-Shaped Composite Feedline for Liquid Hydrogen

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One of the many technological needs in making a single-stage-to-orbit (SSTO) vehicle a reality is being able to reduce component weight. Making components lightweight can lead to an increase in mass fraction and vehicle performance. One area with potential for substantial SSTO weight savings is the use of composite feedlines for the vehicle propulsion system. Typical feedlines for vehicles are made from aluminum or stainless steel materials. It is estimated that a substantial weight savings over conventional metallics could be achieved by using composite feedlines. The potential weight savings makes the use of composite materials a very attractive feature for future SSTO vehicles.

In 1995 under a cooperative agreement contract (NRA8–11) between MSFC and McDonnell Douglas Aerospace, the first composite feedline for liquid hydrogen service was developed. This feedline successfully demonstrated five key technology features that are fundamental in being able to use this material for a feedline application. These five features were the use of graphite/epoxy material, the manufacture and use of composite elbows, the manufacture and use of composite flanges, the ability to join a composite tube to a composite tube, and finally the ability to join a composite tube to a metallic tube. The feedline was designed by McDonnell Douglas and manufactured and tested here at MSFC. The feedline is a part of the auxillary propulsion system on the DC–XA Reusable Launch Vehicle and has been successfully flown on the vehicle. Details on this composite feedline can be found in the *1995 MSFC Research and Technology Annual Report*.

The work performed in 1995 formed the first building block in a whole new area of using composite materials. The next logical step is to expand and improve upon the previous DC–XA vehicle composite feedline work. In October of 1995 a small team of engineers from the Propulsion Laboratory and Materials and Processes Laboratory proposed to the Advanced Propulsion Technology Office here at MSFC a plan for enhancing the prior composite feedline work. This plan was accepted and funded by the MSFC Advanced Propulsion Technology Office. In this plan the MSFC team will design, analyze, manufacture, and test in-house a composite feedline that will demonstrate three more key technology features:

- The ability to manufacture a composite feedline that has a more complex geometry and do it in one piece with composite flanges on both ends.

  The prior composite feedline work for the DC–XA vehicle contained several individual composite components (elbows and flanges) that were joined together using a composite splice joint. Although demonstrating the ability to make joints in a composite feedline was one of the program objectives for the DC–XA vehicle feedline, it is not the ideal way to make a composite feedline. Every bonded joint in a composite feedline is another potential structural failure point and leak point. The MSFC team will build a feedline with no bonded joints, thus eliminating those potential failure points.

  The prior composite feedline work also demonstrated a complex geometry; however, it was only in one plane. On current engines and launch vehicles, the packaging volume is so tight that feedlines are sometimes required to be routed in all three geometric planes, thus taking on a very complex geometry. This MSFC team will build a feedline with a much more complicated geometry than the DC-XA composite feedline and do it in two geometric planes. The geometry proposed will be more typical of those used in feedsystems on launch vehicles. An isometric drawing of the feedline to be built is shown in figure 40.

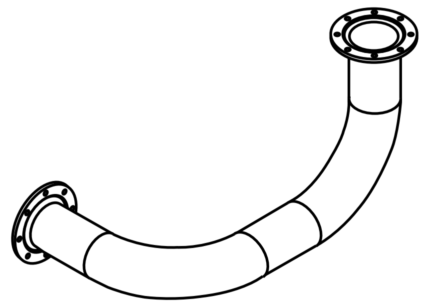

FIGURE 40.—Liquid hydrogen composite feedline.

- The ability to manufacture large diameter composite feedlines.

  The prior composite feedline work for the DC–XA vehicle was for a 2-in-diameter feedline. Although the feedline demonstrated the potential for using composites and saving weight, it did it on a somewhat small scale (2-in-diameter line size). If maximum advantage of using composites to save weight is to be taken, then using this material for the large diameter feedlines found on launch vehicles should be looked at as well. These large diameter feedlines are typically found in the feedsystem located between the propellant tank and engine turbopump interface. On the Space Shuttle these line sizes range from 6 to 17 in in diameter. With these larger diameter feedlines there is significant potential weight savings. The MSFC team will build an 8-in-diameter composite feedline to investigate any potential scale-up problems in going from the previous 2-in-diameter composite feedline.

- The ability to seal composite flanges.

  Since the use of composite flanges for LH_2 service is new technology, there has been very little work performed in the area of how best to seal the composite flanges against LH_2. The MSFC team will evaluate the best flange face design to use along with the best comercially available seal for a composite feedline.

In summary, this technology program will build a composite feedline for LH_2 service. The feedline will have composite flanges on both ends. The feedline design will have a complex geometry by bending in two planes and will have a large diameter of 8 in. It will be manufactured in one piece with no bonded joints and will also incorporate the best seal system for the composite flanges. Performance requirements for the design include:

- Operating pressure: 100 lb/in^2
- Temperature range: –423 degrees Fahrenheit to +150 degress Fahrenheit
- Service life: 20 temperature and pressure cycles
- Leakage rate: Less than $1.0 \times 10E^{-07}$ standard cm^3/sec of gaseous helium at room temperature. Less than 0.14 standard cm^3/sec of hydrogen at cryogenic temperatures.
- Material: IM7/977–3 graphite/epoxy material or an equivalent.

Currently the MSFC team is completing the detail design of the composite feedline. A detail structural analysis of the design is being performed. This analysis will optimize the number of plies and angles in order to meet the performance requirements while minimizing weight. On the manufacturing side, the team is evaluating simple and low-cost methods for manufacturing the tooling necessary to hand-layup the feedline. Several proof-of-concept composite elbows have already been made using a foam mandrel.

Once the best tooling methods have been selected, several development articles will be manufactured. These articles will be subjected to a rigorous test program at MSFC to gain confidence in the design and manufacturing process. Planned tests include: Pressure tests, thermal cycle tests, hydrogen leakage measurement, strength tests, and vibration tests. Once the test articles pass these tests, the full-scale line will be manufactured and it also will go through a series of similar tests.

It is anticipated this program will be complete by August 1997. The success of this program will again advance the technology of using composite materials for launch vehicle feedline applications. This program will not only address the technological aspects but also the issue of making it cost effective.

Tygielski, P.: "A Lightweight, Composite, Liquid Hydrogen Feedline." *1995 MSFC Research and Technology Report*.

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Biographical Sketch: Philip Tygielski graduated from the University of Alabama in Huntsville in 1982 with a bachelor of science degree in mechanical engineering. He currently works in the Mechanical Systems Design Branch of the Propulsion Laboratory at MSFC. Tygielski has been involved in several different vehicle and engine propulsion feedsystem designs for many years. He most recently managed the composite feedline technology program for the DC–XA vehicle.